13 DEMONSTRATING INDISTINGUISHABILITY FROM BACKGROUND

Thus far in this report the emphasis has been on conducting final status surveys that demonstrate that any residual radioactivity in a survey unit is within the release criterion. In these cases, Scenario A is generally preferred for the survey design. In some cases, however, it may be more appropriate to demonstrate indistinguishability from background. Demonstrating indistinguishability from background using Scenario B will be a useful option when the residual radioactivity consists of radionuclides that appear in background, and the variability of the background is relatively high. Background variability may be considered high when differences in estimated mean concentration measured in potential reference areas are comparable to screening level DCGLs.

13.1 Determining Significant Background Variability

In Section 2.2.7, the concept of a reference area was introduced. Any difference in the concentrations between the reference area and the survey unit is assumed to be due to residual radioactivity. It is not possible to determine whether or not an observed difference is actually due to variations in the mean background concentrations between these areas.

When the variations in mean background among different potential reference areas are small compared to the width of the gray region, they can often be neglected. In such cases, the choice of reference area will not materially affect the decision on whether or not to release a survey unit to which it is compared.

As the variations in mean background among different potential reference areas become comparable in magnitude to the width of the gray region, they can no longer be ignored. When the reference area has a higher mean background than the survey unit, the survey unit will be more likely to pass, and when the reference area has a lower mean background than the survey unit, the survey unit will be more likely to fail. Since any difference in background activity between the survey unit and the reference area is attributed to residual radioactivity, the choice of reference area may materially affect the decision on whether or not to release a survey unit to which it is compared.

As an example, consider Figure 13.1, which illustrates a DQO specification for a survey design. The gray region and acceptable rates for decision errors are shown by the solid curve. Suppose the reference area happens to have a lower mean concentration than the actual background concentrations in the survey unit. This difference is depicted by the double-headed arrow. The values of residual radioactivity concentrations in this survey unit will appear larger than they actually are by the amount of that difference. The result is that the actual probability that the survey unit passes is represented by the dashed curve, which is shifted downward from the solid curve by the difference in mean background between the survey unit and the reference area. This means, for example, that when the true residual radioactivity concentration is at the LBGR there is only about a 65% probability of passing this survey unit, rather the 95% probability specified in the DQO.

Exactly how much, and in which direction the probabilities shift will depend on the particular

reference area. Under such circumstances, whether a survey unit passes or fails may depend more on the particular reference area chosen than on the amount of residual radioactivity that it contains. This leads to a quantitative definition of what it means for a survey unit to be indistinguishable from background. It is expressed in terms of the potential for variations in reference area mean concentrations to impact decision error rates. First, it is necessary to establish that there is significant variability among potential reference areas. A procedure for doing this is discussed in the next section. If it shown that significant variability exists, this information is used to define a level of residual radioactivity concentration that is indistinguishable from background variations. Section 13.4 discusses how this can be used to plan a final status survey using Scenario B.

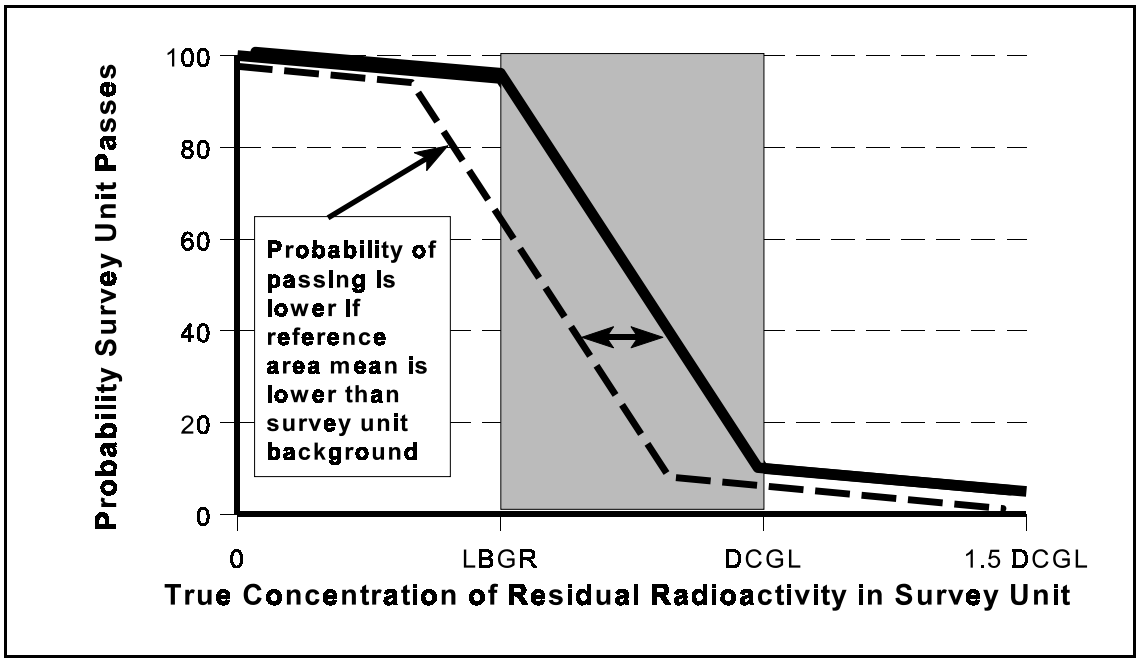

Figure 13.1 Impact of Background Variability on Decision Errors

13.2 Determining if Reference Areas Have Significantly Different Background Levels

In this section, we focus our attention on potential reference areas. Consider all the reference areas to which a particular survey unit may be compared according to the criteria set out in Section 2.2.7. To determine whether there are significant differences among the reference area background means, the reference area measurements are expressed as:

$$x_{ij} = \xi + \mu_i + z_{ij} \qquad (13\text{-}1)$$

where

x_{ij} = the jth measurement in the ith reference area, for $j = 1$ to n_i, the number of measurements in the ith reference area, and for $i = 1$ to k, the number of reference areas

ξ = the mean concentration over all reference areas

μ_i = the difference between the overall mean and the mean in the ith reference area

z_{ij} = the contribution of random spatial and measurement variability to the jth measurement in the ith reference area

ξ is an unknown constant. The μ_i are distributed across reference areas with mean zero and standard deviation ω, but within reference area i, μ_i has a fixed value. The z_{ij} have mean zero and standard deviation σ. The measurements within reference area i have mean $\xi + \mu_i$, and variance σ^2. The reference area means are distributed around the overall mean ξ with variance deviation ω^2. Thus, if there is no variability in the reference area means, then $\omega^2 = 0$. The measurement variability within each reference area is σ^2, and it is the same whether or not there is a significant difference among the reference area means.

If the μ_i and the z_{ij} are assumed to be normally distributed, the above corresponds to a random effects one-way analysis of variance model, sometimes called Model II. ω^2 and σ^2 are called the components of variance. The null hypothesis, $\mathbf{H_0}$: $\omega^2 = 0$, versus the alternative, $\mathbf{H_a}$: $\omega^2 > 0$, is tested parametrically with an F-test. The non-parametric equivalent is the Kruskal-Wallis test.

Before collecting data for the Kruskal-Wallis test, the acceptable Type I error rate, α_{KW}, must be specified. This is the acceptable probability of concluding that the reference areas have different average concentrations, when in fact they are the same. In setting α_{KW} it is important to consider that the risk involved in a Type I error may be much smaller than the risk of a Type II error.

To perform the Kruskal-Wallis test, all of the measurements from the reference areas are pooled and ranked. For every measurement, x_{ij} , there is a corresponding rank, r_{ij} . There will be $N = n_1 + n_2 + ... + n_k$ measurements in all. The sum of all of the ranks is $N(N+1)/2$. Therefore the average rank is $N(N+1)/(2N) = (N+1)/2$. If the distribution of measured concentrations in each reference area is the same, then the average rank for each reference area, should also be about the same, i.e., $(N+1)/2$.

Let

$$\overline{R_i} = \frac{1}{n_i} \sum_{j=1}^{n_i} r_{ij} = R_i / n_i \qquad (13\text{-}2)$$

be the average rank in reference area i. The quantity $\overline{R_i} - (N+1)/2$ is a measure of how different this reference area is from the others.

The Kruskal-Wallis statistic is a weighted sum of the squares of these differences over all of the reference areas:

$$K = \frac{12}{N(N+1)} \sum_{i=1}^{k} n_i \left(\overline{R_i} - (N+1)/2 \right)^2 = \frac{12}{N(N+1)} \left(\sum_{i=1}^{k} R_i^2 / n_i \right) - 3(N+1) \qquad (13\text{-}3)$$

The weights in Equation 13-3 have been chosen so that the probability that K exceeds a given value K_c , may be approximated by a chi-squared distribution with $k-1$ degrees of freedom:

$$\text{Prob}(K > K_c) = 1 - \chi^2_{k-1}(K_c) \qquad (13\text{-}4)$$

The critical value K_c is determined from setting $\chi^2_{k-1}(K_c) = \alpha_{KW}$. Values of $\chi^2_{k-1}(K_c)$ for typical values of α_{KW} are tabulated in Table 13.1. If the value of K computed from Equation 13-3 exceeds K_c, then the null hypothesis is rejected.

Table 13.1 Critical Values, K_c, for the Kruskal-Wallis Test

α_{KW}					
$k-1$	**0.01**	**0.025**	**0.05**	**0.1**	**0.2**
1	6.6	5.0	3.8	2.7	1.6
2	9.2	7.4	6.0	4.6	3.2
3	11.3	9.3	7.8	6.3	4.6
4	13.3	11.1	9.5	7.8	6.0
5	15.1	12.8	11.1	9.2	7.3
6	16.8	14.4	12.6	10.6	8.6
7	18.5	16.0	14.1	12.0	9.8
8	20.1	17.5	15.5	13.4	11.0
9	21.7	19.0	16.9	14.7	12.2
10	23.2	20.5	18.3	16.0	13.4

For example, suppose there are four reference areas under consideration, and ten measurements are made in each. The data and the ranks are shown in Table 13.2. The same type of spreadsheet functions that were used for the WRS test can also be used to calculate the ranks for the Kruskal-Wallis test.

Using Equation 13-2,

$$K = \frac{12}{N(N+1)} \left(\sum_{i=1}^{k} R_i^2/n_i \right) - 3(N+1)$$

$$= \frac{12}{40(41)} \left(155^2/10 + 121^2/10 + 255^2/10 + 289^2/10 \right) - 3(41)$$

$$= \frac{12}{1640} (2402.5 + 1464.1 + 6502.5 + 8352.1) - 123 = \frac{12}{1640} (18721.2) - 123.0 = 14.0$$

With $k-1 = 3$, this value of K, is greater than the highest value of K_c in Table 13.1, viz., 11.3 for $\alpha_{KW} = 0.01$. The null hypothesis is rejected. It is concluded that these reference areas do have significantly different concentration distributions.

Table 13.2 Example Data for the Kruskal-Wallis Test

	Measurements					Ranks			
	Area 1	Area 2	Area 3	Area 4		Area 1	Area 2	Area 3	Area 4
1	0.27	1.04	2.45	3.77		6	13	27	39
2	1.87	0.39	0.34	2.63		20	9	8	31
3	0.97	2.07	3.06	4.05		10	23	37	40
4	1.01	−0.57	2.83	1.72		11	2	35	19
5	2.08	1.97	1.09	1.50		24	21	14	17
6	1.62	−0.22	0.26	2.47		18	3	5	29
7	0.30	1.39	2.80	1.42		7	15	34	16
8	1.98	0.05	2.77	2.47		22	4	33	28
9	2.18	−0.75	2.42	2.76		25	1	26	32
10	1.02	2.50	2.86	3.35		12	30	36	38
Mean	1.33	0.79	2.09	2.61	Sum	155	121	255	289
StdDev	0.71	1.17	1.09	0.91	Total				820

13.3 Establishing the Concentration Level That Is Indistinguishable

Once it is decided that there are significant differences among the potential reference areas for a survey unit, a measure of the variability among these reference areas is needed.

The sample mean of the measurements in area *i* is

$$\overline{x_i} = \frac{1}{n_i} \sum_{j=1}^{n_i} x_{ij} \tag{13-5}$$

which provides an estimate of the mean concentration in reference area *i*, namely $\xi + \mu_i$.

The overall sample mean

$$\overline{x} = \frac{\sum_{i=1}^{k} \sum_{j=1}^{n_i} x_{ij}}{\sum_{i=1}^{k} n_i} \tag{13-6}$$

is an estimate of the overall mean background concentration, ξ .

The sample variance of the measurements in area *i* is

$$s_i^2 = \sum_{j=1}^{n_i} (x_{ij} - \bar{x}_i)^2 / (n_i - 1) = \sum_{j=1}^{n_i} (z_{ij} - \bar{z}_i)^2 / (n_i - 1) \qquad (13\text{-}7)$$

which is an estimate of σ^2.

Since σ^2, is assumed to be the same in each reference area, these estimates can be pooled into the following estimate:

$$s_w^2 = \frac{\sum_{i=1}^{k} \sum_{j=1}^{n_i} (x_{ij} - \bar{x}_i)^2}{\sum_{i=1}^{k} (n_i - 1)} = \frac{\sum_{i=1}^{k} \sum_{j=1}^{n_i} x_{ij}^2 - \sum_{i=1}^{k} n_i (\bar{x}_i)^2}{\sum_{i=1}^{k} (n_i - 1)} \qquad (13\text{-}8)$$

In the analysis of variance, s_w^2 is called the mean square within reference areas[(1)].

The mean square between reference areas is

$$s_b^2 = \frac{\sum_{i=1}^{k} n_i (\bar{x}_i - \bar{x})^2}{k - 1} = \frac{\sum_{i=1}^{k} n_i (\bar{x}_i)^2 - \left(\sum_{i=1}^{k} \sum_{j=1}^{n_i} x_{ij} \right)^2 \Big/ \sum_{i=1}^{k} n_i}{k - 1}$$

The righthand sides of Equations 13-8 and 13-9 may appear imposing, but essentially only involve:

(1) the sum of the squares of all the measurements,

$$\sum_{i=1}^{k} \sum_{j=1}^{n_i} x_{ij}^2 \qquad (13\text{-}10)$$

[(1)] The sum of the squared differences from the overall mean is composed of two parts:

$$\sum_{i=1}^{k} \sum_{j=1}^{n_i} (x_{ij} - \xi)^2 = \sum_{i=1}^{k} \sum_{j=1}^{n_i} (x_{ij} - \bar{x}_i)^2 + \sum_{i=1}^{k} \sum_{j=1}^{n_i} (\bar{x}_i - \xi)^2 = \sum_{i=1}^{k} \sum_{j=1}^{n_i} (x_{ij} - \bar{x}_i)^2 + \sum_{i=1}^{k} n_i (\bar{x}_i - \xi)^2$$

The first term on the right hand side is the sum of squares within reference areas and the second term on the right hand side is the sum of squares between reference areas. The mean square is obtained by dividing the sum of squares by the degrees of freedom. For the means square within reference areas this is the total number of data points minus the number of reference areas. For the means square between reference areas this is the number of reference areas minus one.

(2) the square of the sum of all the measurements,

$$\left(\sum_{i=1}^{k}\sum_{j=1}^{n_i} x_{ij}\right)^2 \qquad (13\text{-}11)$$

and

(3) the sum of the squares of the reference area averages weighted by the number of measurements,

$$\sum_{i=1}^{k} n_i\left(\bar{x}_i\right)^2 \qquad (13\text{-}12)$$

The component of variance, ω^2, is estimated by

$$\hat{\omega}^2 = (s_b^2 - s_w^2)/n_0 \quad \text{where} \quad n_0 = \frac{N - \sum_{i=1}^{k} n_i^2/N}{(k-1)} \qquad (13\text{-}13)$$

n_0 is usually slightly less than the average number of samples taken in each reference area,

$$\bar{n} = \frac{1}{k}\sum_{i=1}^{k} n_i \qquad (13\text{-}14)$$

If the number of measurements in each reference area is the same, $n_1 = n_2 = ... = n_k = n$, then,

$$n_0 = \frac{N - \sum_{i=1}^{k} n_i^2/N}{(k-1)} = \frac{N - kn^2/N}{(k-1)} = \frac{kn - kn^2/kn}{(k-1)} = \frac{kn - n}{(k-1)} = \frac{n(k-1)}{(k-1)} = n \qquad (13\text{-}15)$$

The calculation of $\hat{\omega}^2$ for the example data of Table 13.2 proceeds using the sums and squares shown in Table 13.3.

The sums (1), (2), and (3) together with s_b^2 and s_w^2 are calculated from Table 13.3 as follows:

From Equation 13-10,
(1) = sum of squares = 22.28 + 18.50 + 54.30 + 75.80 = 170.88.

From Equation 13-11,
(2) = square of the sum = $(13.30 + 7.87 + 20.88 + 26.14)^2 = (68.19)^2 = 4649.88$.

From Equation 13-12,
(3) = weighted sum of the squares of the averages $10(1.33^2 + 0.79^2 + 2.09^2 + 2.61^2)$
= $10(1.77 + 0.62 + 4.36 + 6.83) = 10(13.58) = 135.8$.

From Equation 13-8,
$s_w^2 = (170.88 - 135.8)/(N-k) = (170.88 - 135.8)/36 = 0.97$.

From Equation 13-9,
$s_b^2 = (135.8 - (4649.88/N))/(k-1) = (135.8 - (4649.88/40))/(3) = 6.52$.

Finally, we have

$$\hat{\omega}^2 = (s_b^2 - s_w^2)/n_0 = (6.52 - 0.97)/10 = 0.55 \qquad (13\text{-}16)$$

Table 13.3 Calculation of $\hat{\omega}^2$ for the Example Data

	Measurements				Measurements Squared			
	Area 1	**Area 2**	**Area 3**	**Area 4**	**Area 1**	**Area 2**	**Area 3**	**Area 4**
1	0.27	1.04	2.45	3.77	0.07	1.08	6.00	14.21
2	1.87	0.39	0.34	2.63	3.50	0.15	0.12	6.92
3	0.97	2.07	3.06	4.05	0.94	4.28	9.36	16.40
4	1.01	−0.57	2.83	1.72	1.02	0.32	8.01	2.96
5	2.08	1.97	1.09	1.50	4.33	3.88	1.19	2.25
6	1.62	−0.22	0.26	2.47	2.62	0.05	0.07	6.10
7	0.30	1.39	2.80	1.42	0.09	1.93	7.84	2.02
8	1.98	0.05	2.77	2.47	3.92	0.00	7.67	6.10
9	2.18	−0.75	2.42	2.76	4.75	0.56	5.86	7.62
10	1.02	2.50	2.86	3.35	1.04	6.25	8.18	11.22
sum	13.30	7.87	20.88	26.14	22.28	18.50	54.30	75.80
average	1.33	0.79	2.09	2.61				
avg sqd	1.77	0.62	4.36	6.83				

Although the analysis of variance using the F-test requires the assumption that the data are normally distributed, the calculation of $\hat{\omega}^2$ does not. Therefore, the values of the mean squares s_b^2 and s_w^2 that are generated by most statistical computer programs for ANOVA can be used for these calculations. Table 13.4 shows an ANOVA for the example data generated by a spreadsheet program. The entry for the mean square within groups, 0.97, is the same as was found in Table 13.3 for s_w^2. Similarly, the entry for the mean square between groups, 6.52, is the same as was found in Table 13.3 for s_b^2. The F-statistic, which is simply the ratio s_b^2/s_w^2, is also shown. Of course, if the data from each reference area are consistent with the assumption of normality, the F-test may simply be used instead of the Kruskal-Wallis test.

Table 13.4 Analysis of Variance for Example Data

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F Statistic
Between Groups	19.56	3	6.52	6.69
Within Groups	35.08	36	0.97	
Total	54.65	39		

13.4 Using the Concentration Level That Is Indistinguishable in the WRS Test

Recall from Section 3.6, that in Scenario B, the hypotheses being tested are

Null Hypothesis:
H_0: The mean concentration of residual radioactivity in the survey unit is indistinguishable from background up to a level specified by the LBGR.
versus
Alternative Hypothesis:
H_a: The mean concentration of residual radioactivity in the survey unit distinguishable from background is in excess of the $DCGL_W$.

In this scenario, a Type I decision error, with associated probability α, is made when a survey unit fails when it should pass. A Type II decision error, with associated probability β, is made when a survey unit passes when it should fail. To set these decision errors, an appropriate gray region is needed. The lower bound on this gray region is the concentration level above background that may be considered distinguishable from background.

If the null hypothesis of Kruskal-Wallis test has been rejected, the mean background levels among reference areas varies about the overall mean ξ with a standard deviation estimated by $\hat{\omega}$. The difference in concentration that is distinguishable above background variability may be expressed in terms of an appropriate multiple of $\hat{\omega}$. For example, if the reference area means are normally distributed, the probability that the survey unit mean is more than two standard deviations away from the overall mean is about 5%. Regardless of how the data are distributed, Chebyshev's Inequality states that the probability that the true mean background in the survey unit differs from the overall mean background by more than t standard deviations is less than $1/t^2$. Therefore, the probability that the survey unit mean is more than $t = 2$ standard deviations away from the overall mean is less than $1/t^2 = 1/4 = 25\%$. The probability that the survey unit mean is more than $t = 3$ standard deviations away from the overall mean is less than $1/t^2 = 1/9 = 11\%$. In most cases, it is reasonable to assume that the true probabilities will fall somewhere between the value calculated for the normal distribution and that established by Chebyshev's inequality. The multiple that of $\hat{\omega}$ that is used in a specific application should be decided during the DQO process, but a factor of three is a reasonable default.

For the example data $\hat{\omega}^2 = 0.55$ so $\hat{\omega} = 0.74$. Thus, differences smaller than $3\hat{\omega} = 2.22$ would not be considered distinguishable from background variations. Notice that in Table 13.2, the difference in the means between reference areas #4 and #2 is $2.61 - 0.79 = 1.82$.

The WRS test is applied as described in Section 6.3, using the decided upon multiple of $\hat{\omega}$ as the LBGR, and the width of the gray region equal to the $DCGL_W$. The hypotheses tested by the WRS under Scenario B are restated as

Null Hypothesis:

H_0: The difference in the median concentration of radioactivity in the survey unit and in the reference area is less than the LBGR.

versus

Alternative Hypothesis:

H_a: The difference in the median concentration of radioactivity in the survey unit and in the reference area is greater than the $DCGL_W$.

The Type I error rate $\alpha_W = \alpha/2$[(2)], is the probability that a survey unit with a difference from the reference area equal to the LBGR will fail the test. The power, $1-\beta$, is the probability that a survey unit with a difference at the $DCGL_W$ above the LBGR will fail the test. For example, the desired probability for the survey unit passing might look similar to Figure 13.2.

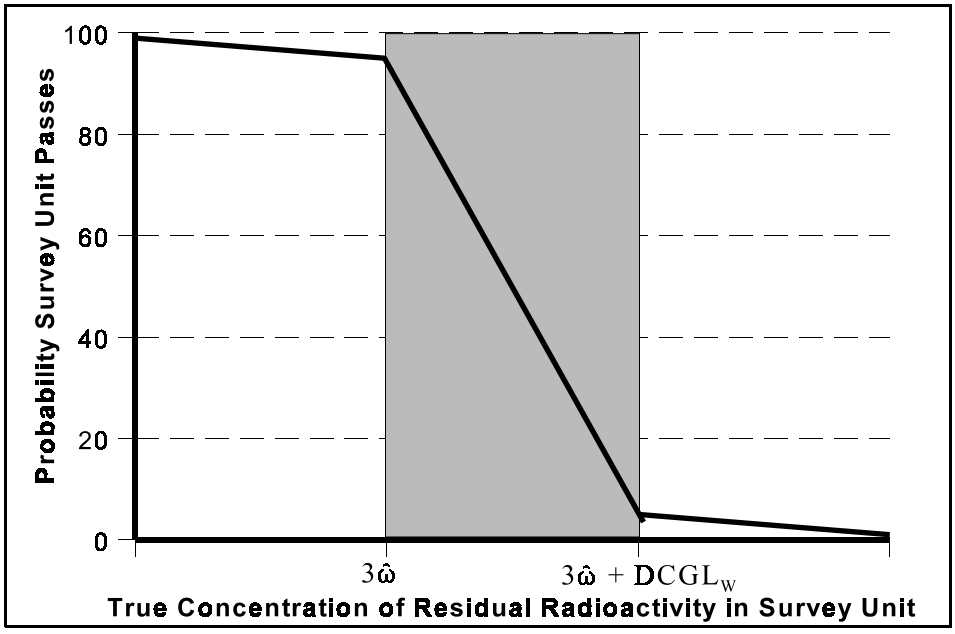

Figure 13.2 Example DQOs for the Probability That the Survey Unit Passes Versus the Concentration Difference Between the Survey Unit and the Reference Area

(2) Recall that since the Quantile test is performed in tandem with the WRS test, $\alpha_W = \alpha_Q = \alpha/2$, so that the that the size of the two tests in tandem is approximately $\alpha = \alpha_Q + \alpha_W$.

The Quantile test is also performed as described in Section 7.2, with $\alpha_Q = \alpha/2$, and with the LBGR equal to the decided upon multiple of $\hat{\omega}$.

All of the reference area measurements taken for the Kruskal-Wallis test should also be used in the WRS and Quantile tests. In most cases, no additional reference area samples will be needed. If additional samples are required, they should be obtained randomly, with all of the reference areas being equally likely to be sampled.

13.5 Determining the Number of Reference Areas and the Number of Samples

In applying the methods of this chapter, it is natural to ask is how many reference areas should be studied, and how many samples should be taken in each. As was seen in Section 3.8.1, the number of samples needed depends on both the probability of a Type I error (α) and the probability of a Type II error (β) that are deemed acceptable for the test. Unfortunately, the power ($1-\beta$) of the Kruskal-Wallis test involves functions that are "too complicated to be useful" (Lehmann and D'Abrerra, 1975). However, it has been shown that the efficiency of the Kruskal-Wallis test relative to the F-test is the same as the efficiency of the WRS test to the t-test (Andrews, 1954). This means that one can get an approximate idea of the power of the Kruskal-Wallis test by calculating the power of the F-test.
The power of the F-test is (Brownlee, 1960, p.268):

$$1-\beta = Probability[F(f_1,f_2) > \frac{1}{\phi} F_{1-\alpha}(f_1,f_2)] \qquad (13\text{-}17)$$

where

$\phi = 1 + n\frac{\omega^2}{\sigma^2}$, and $F_{1-\alpha}(f_1,f_2)$ is the $1-\alpha_{KW}$ percentile of the F distribution with $f_1 = k - 1$ and $f_2 = kn-k$ degrees of freedom. Through ϕ, the power depends on the ratio of the variance components. Under the null hypothesis, $\omega^2 = 0$, so $\phi = 1$.

As an example, consider the data from Table 13.2. If one wished to detect a situation in which $\omega^2 = \sigma^2$, then $\phi = 1 + 10(1) = 11$. If $\alpha_{KW} = 0.1$, then $F_{1-\alpha}(f_1,f_2) = F_{0.9}(3,36) = 2.243$. The power, $1-\beta$, is then the probability that the F-statistic with 3 and 36 degrees of freedom exceeds $2.243/\phi = 2.243/11 = 0.2039$. β is the probability that the F-statistic with 3 and 36 degrees of freedom is less than 0.2039. This probability is about $\beta = 0.1$, so the power is about 0.9.

The results of this calculation for other numbers of samples and reference areas are shown in Table 13.5 for $\alpha_{KW} = 0.05$, 0.10 and 0.20. Although this is only an approximation, and the actual power of the Kruskal-Wallis test would be slightly lower, this table indicates that with four reference areas each with between 10 and 20 samples in each should generally be adequate. Since the risk of not detecting background variations that are actually present (a Type II error) could involve the impossible task of remediating background, choosing a higher value for α_{KW} than for β would often be justified. From Table 13.5, when $k = 4$, this implies that $\alpha_{KW} = 0.1$ is a reasonable default, and in some circumstances even larger values could be considered.

Table 13.5 Power of the F-test When $\omega^2 = \sigma^2$

Number of reference areas (k)	Number of samples in each (n)	Total Number of Samples (kn)	ϕ	Power when $\alpha_{KW} = 0.05$	Power when $\alpha_{KW} = 0.1$	Power when $\alpha_{KW} = 0.2$
2	10	20	11	53.4%	60.7%	69.3%
2	15	30	16	61.3%	67.4%	74.5%
2	20	40	21	66.1%	71.5%	77.7%
2	30	60	31	72.1%	76.5%	81.7%
3	10	30	11	74.0%	79.7%	85.7%
3	15	45	16	81.8%	85.9%	90.1%
3	20	60	21	86.1%	89.2%	92.4%
3	30	90	31	90.5%	92.7%	94.9%
4	10	40	11	85.3%	89.3%	93.0%
4	15	60	16	91.4%	93.8%	96.0%
4	20	80	21	94.2%	95.8%	97.3%
4	30	120	31	96.7%	97.6%	98.5%
5	10	50	11	91.8%	94.3%	96.5%
5	15	75	16	95.9%	97.2%	98.3%
5	20	100	21	97.6%	98.4%	99.0%
5	30	150	31	98.9%	99.2%	99.5%
6	10	60	11	95.4%	97.0%	98.3%
6	15	90	16	98.1%	98.8%	99.3%
6	20	120	21	99.0%	99.4%	99.6%
6	30	180	31	99.6%	99.8%	99.9%

13.6 Determining When Demonstrating Indistinguishability Is Appropriate

The methods of this chapter were developed specifically to address potential difficulties with demonstrating compliance with dose-based release criteria at sites with spatially variable background concentrations of natural radionuclides. Generally, the use of Scenario A is preferred since it involves fewer assumptions in its application and requires only one statistical test. The null hypothesis for Scenario A is such that when the residual radioactivity in the survey unit is very close to the $DCGL_W$, the default decision is to not release the survey unit without further investigation. This provides additional assurance that the release criteria will not be exceeded. However, when the variability in background is high, this assurance comes at too high a price, namely the possibility of requiring remediation of survey units containing only background concentrations of radionuclides. Since the default decision in Scenario B is to release the survey unit, a second statistical test, the Quantile test, is used to detect non-uniform concentrations of

residual radioactivity that may be excess of the release criterion, but that might be missed by the WRS test..

It is not possible to anticipate every circumstance in which these methods might be considered applicable. The suitability of these methods to specific situations should be determined during the DQO process. Two factors that should be considered in making this determination are:

(1) Have reasonable efforts been made to reduce measurement uncertainty. e.g., by use of radionuclide-specific methods?

(2) Have reasonable efforts been made to reduce spatial variability by choosing homogeneous survey units with well-matched reference areas?

Once it is determined that the methods of this chapter are appropriate, the error rates for the Kruskal-Wallis test should be set. The Kruskal-Wallis test is used to determine whether the spatial variability of average reference area background concentrations is significant. The significance level is . If adequate consideration has been given to the decision to demonstrate indistinguishability, α_{KW} need not be set to too low a value. Indeed, if it is felt that background variability should always have the benefit of the doubt, the Kruskal-Wallis test need not be conducted. Not conducting the test is essentially the same as setting α_{KW} = 1.0. Table 13.5 could still be used as a guide in determining the number of reference areas, and the number of measurements in each, that will be used to estimate $\hat{\omega}$ according to the procedures of Section 13.3.

Finally, the appropriate multiple of $\hat{\omega}$ to be used as the LBGR should be determined. The discussion of this issue in Section 13.4 can be used as a guide.